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EQUIPMENT SELECTION AND UTILIZATION IN SURFACE MINING

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May 1986

Energy Research Program
Coal Research Laboratories
Division Report ERP/CRL 86-66(TR)

35 pp

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MICROMEDIA

EQUIPMENT SELECTION AND UTILIZATION IN SURFACE MINING

BY

R.K. SINGHAL

ABSTRACT

This report reviews some of the equipment and systems used on a major scale for loading and transportation in surface mining with emphasis on procedures for equipment selection.

Scraper, front-end loaders and shovels are the mainstay of surface mining industry for loading. Trucks are used extensively for transporation. Conveyors are currently in use for out-of-pit long-haul transportation. However recent developments in conveyor transportation technology has enhanced their portability and mobility such that they are finding acceptance in in-pit transportation. New developments such as hydraulic bucketwheels, high angle conveyors and application of micro-processor based monitoring technology are also described.

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SÉLECTION ET UTILISATION DE L'APPAREILLAGE REQUIS POUR LES TRAVAUX D'EXPLOITATION MINIÈRE À CIEL OUVERT

par

R.K. Singhal

RÉSUMÉ

Le présent rapport porte sur une partie de l'appareillage et des systèmes utilisés sur une grande échelle pour le chargement et le transport dans les travaux d'exploitation minière à ciel ouvert et fait ressortir l'importance des méthodes de sélection.

Dans les mines à ciel ouvert, les bennes racleuses, les tracto-chargeurs et les pelles sont les machines les plus fréquemment utilisées pour le chargement. Les camions constituent le principal moyen de transport. Les convoyeurs sont actuellement utilisés pour le transport sur de longues distances à partir de la carrière. Cependant, les développements récents des techniques de transport par convoyeur ont contribué à améliorer la mobilité de ces machines et à faciliter leur transport de sorte qu'il est maintenant possible de les utiliser pour le transport des matériaux à l'intérieur de la mine. Les développements récents, tels le convoyeur hydraulique à roue-pelle, le convoyeur à bande dont l'angle est presque droit ainsi que l'application des techniques de surveillance par micro-processeur sont également présentés.

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INTRODUCTION

In surface mining equipment operating costs are generally more than half of total operating costs. To control costs, therefore optimal selection of equipment is vital. Proper equipment selection and utilization can often make the difference between a profitable mining operation and a failure or at best a marginal operation. Main considerations in primary equipment selection are the geology of the deposit, production requirement, project life, capital availability, operating cost, geotechnical parameters and resource recovery. In simple terms the factors which influence equipment selection, sizing and utilization are given in Fig (1). Of these, the terms of reference and site specific parameters are the most important.

A wide variety of equipment is used for material excavation in surface mining including scrapers, electric cable shovels, front-end loaders, hydraulic shovels, draglines and bucketwheels. Various types of haulage trucks, conveyors, scrapers, trains and pipelines are used for transporting the excavated material.

SCRAPERS/FRONT END LOADERS/SHOVELS

Scraper, front-end loaders and electric cable shovels comprise the traditional loading equipment for surface mining industry.

Many types of scrapers are available. They are highly mobile machines, capable of selective mining and have an excellent weight to horse power ratio. They can climb grades approaching 45° and are most productive in softer materials. Scrapers are used for maintaining pit roads, digging ditches, general clean up work around the pit and for blending on stockpiles. Fig. 2 provides a capability chart for each type of scraper. Table illustrates the range of application of various types of scrapers.

Diesel powered front end loaders are highly mobile machines and capable of giving high production in good blasted rock. Front end loaders are being increasingly used a s load and carry machines performing both the excavation and face haulage functions. A typical example is the application where a front-end loaders(s) excavates from a pit bank and hauls the meterial to hopper or hopper/crusher for placement of the material on a conveyor system. Another system worth mentioning is the situation where front-end loaders are used in the staggered tandem and chain loadig system (Fig.3).

Electric cable shovels generally have low operating and maintenance costs, can handle coarse materials and are very robust machines with a life span of 20 to 30 years. Their main drawback is low mobility. They are also limited by steep grades, have limited selective mining capability and require support equipment e.g. dozer or wheel loader.

A newer development combining the operating merits of a shovel and a front-end loader is the hydraulic shovel. Most of the hydraulic shovels

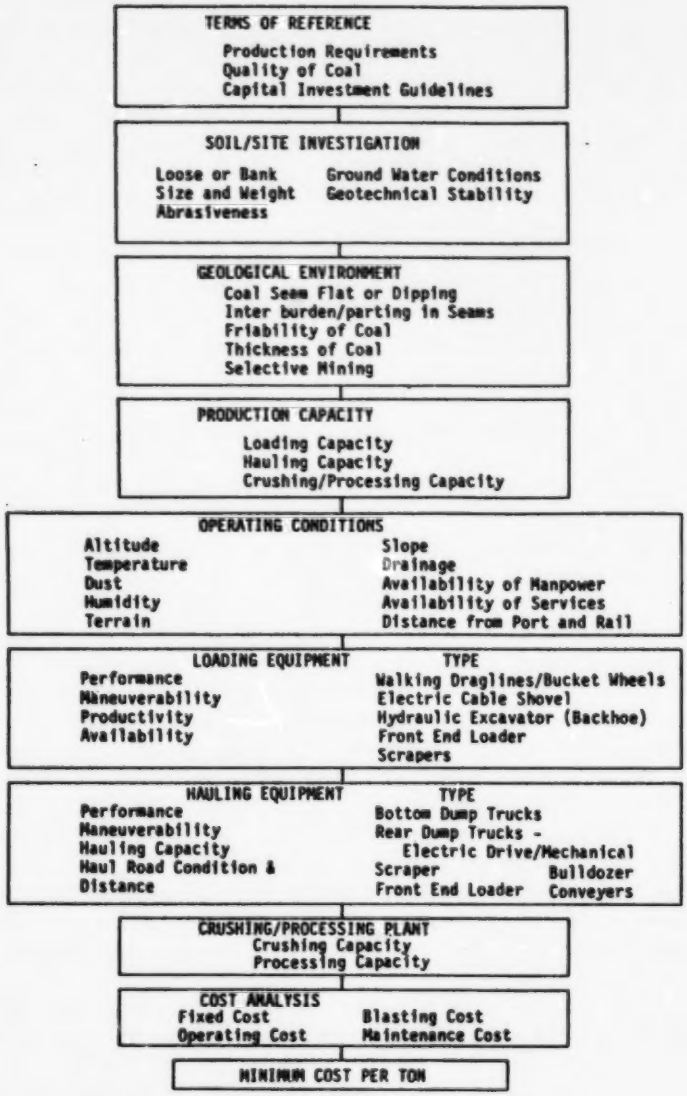


Fig 1. FLOW CHART - Mine Equipment Selection

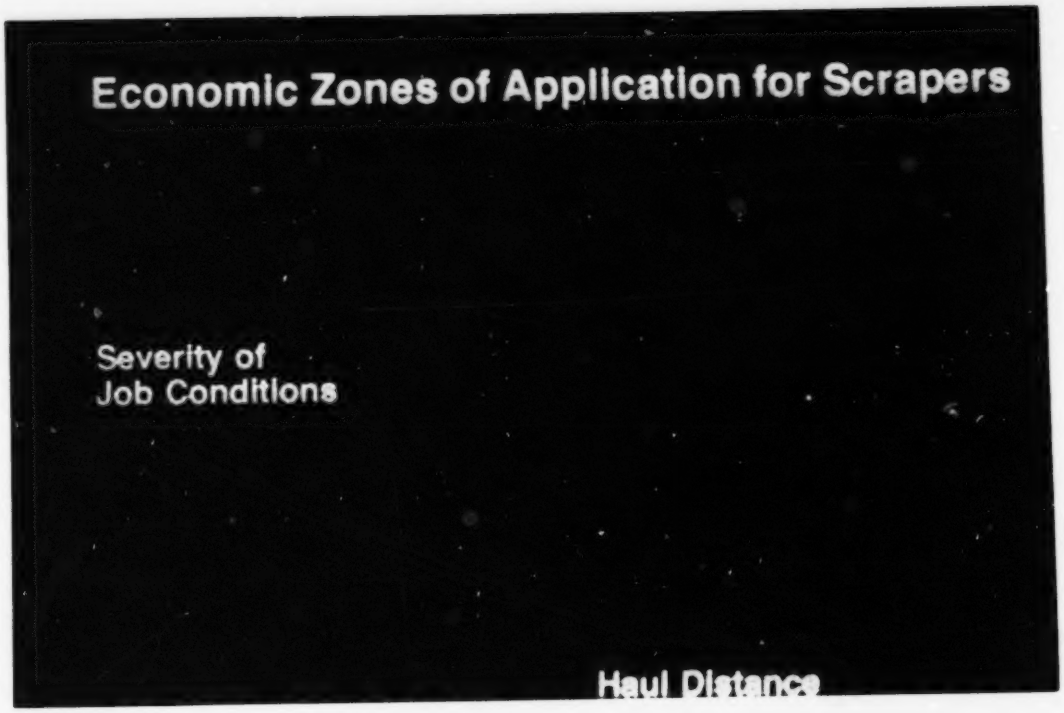


Fig 2. Economic zones of application for scraper-compatibility chart

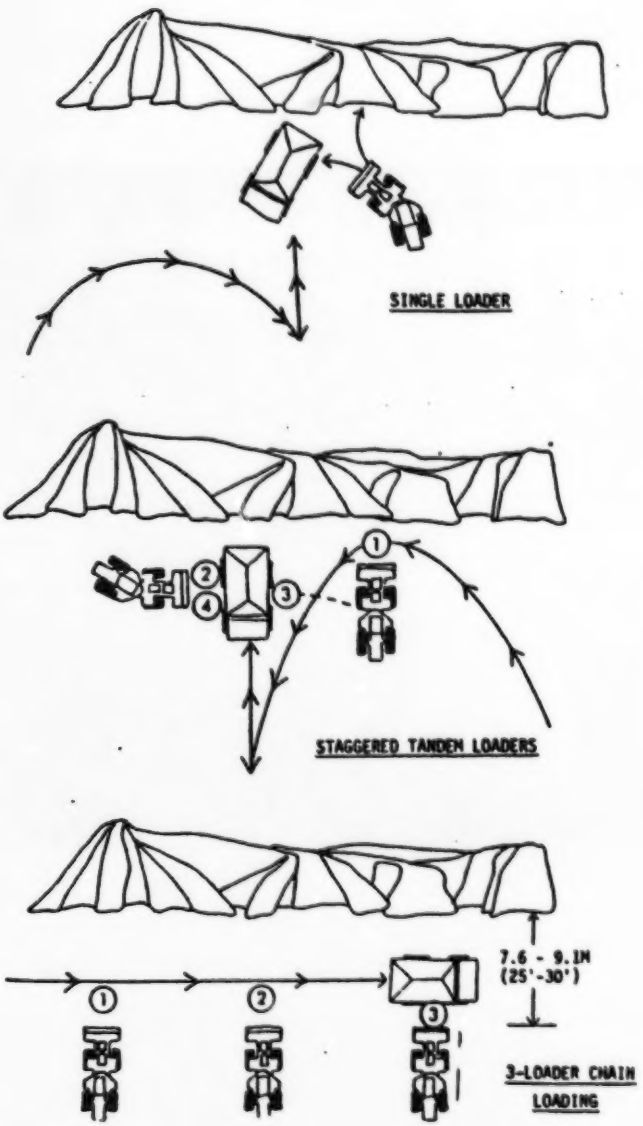


Fig 3. STAGGERED TANDEM AND CHAIN LOADING FOR FRONT END LOADER/TRUCK SYSTEM

Table 1.

Factors to Consider in Scraper Selection

Conventional Scraper	Tandem Powered Scraper	Elevating Scraper	Push-Pull Scraper
Type of Material			
1) has the widest range of application due to a pusher.	1) range slightly less than that of conventional scrapers—tire costs can be higher.	1) not advised beyond gravel because of high tire wear and elevator mechanism cost.	1) most limited due to tire cost but range can be increased when push loaded.
Grade Resistance, Rolling Resistance (RR) and Haul Distance			
2) economical.	2) economical in situations where its high cost is offset by its greater horse power and increased tractive effort.	2) most economical for short hauls—600 m on low rolling resistance and low grades.	2) most flexible—can work in all areas where tandem powered scraper can work, can handle short hauls, high RR, etc., must have 75-m cut areas as minimum.
3) can climb grades of 25% empty and 15% loaded. Suitable for level and moderate grades on good haul roads.	3) can climb grades approaching 45%. Can also work in wet weather or in poor underfoot conditions, unlike single engine scrapers.	3) can work alone, does not need a pusher and thus not vulnerable to mis-match. Often used to supplement conventional scrapers.	3) newest type where two modified tandem powered scrapers are placed in line and temporarily connected for loading. Needs no pusher, so no scraper/pusher mismatch, no bunching.
4) excellent all-around scraper.	4) excellent where a low, weight to horse power ratio is needed.	4) elevator mechanism conditions the materials for better dumping and spreading.	4) extremely flexible machine.

available are diesel powered. A recent important trend, however, is to use electric power instead of diesel. This option has advantages in situations where the machine is being used as a main production unit, not requiring frequent moves. An electrically operated machine has lower operating cost and is not so noisy.

Table (2) provides a comparison of operating characteristics of a front end loader, electric cable shovel and a hydraulic shovel.

The hydraulic shovel has proved very effective in selective mining. The wrist action of this type of machine allows for efficient separation of waste from ore and reduces the downstream cost of screening and processing When converted to a backhoe the shovel can be used to mine inclined and folded seams. The units greater breakout force makes them ideal for loading compacted materials. (Figs 4 & 5).

In many situations the hydraulic shovel has replaced the conventional shovel and front-end loaders. Hydraulic shovels were once actively used with a bucket size of up to $20m^3$. Now they are competing with other loading equipment with bucket capacities of the $30m^3$ range. O&Ks hydraulic shovel RH300 is the largest machine available with a bucket of $34m^3$.

From Table (3) it is clear that for a similar size of bucket the weight of a hydraulic shovel is approximately one half that of a cable shovel. It has a speed of travel nearly twice that of cable shovels. The service life of flat shoe tracks is greatly reduced when power shovels travel for long distances. By comparison, hydraulic loading shovels are generally mounted on crawlers similar to those of heavy-duty bulldozers and their mobility is about that of a bulldozer - with a traveling speed of about 2.0 km/hr.

Table 3. Conventional Cable shovel VS. Hydraulic shovel ($23m^3$ bucket)

	Cable Shovel	Hydraulic Shovel
Drive Power (kW)	1450	1570
Ground Pressure (N/CM^2)	26	14
Travel Speed (km/hr)	1.16	2.10
Bucket Volume (m^3)	23	23
Operating weight (t)	885	485

Hydraulic shovels are versatile (Fig 6,7,8). With bullclam buckets, they are used for stripping overburden and mining ore in hard and soft rock

Table 2.

Comparison of Operating Characteristics of Hydraulic Shovel, Electric Cable Shovel and Front End Loader

Hydraulic Shovel	Electric Cable Shovel	Front-End Loader
Powerful digging force permits the machine to operate in a variety of conditions. To operate with an equivalent capacity bucket it requires roughly half the hoist and crowd needed by an electric cable shovel It can dig above and below the floor level; can be used as a back hoe. Effective application of digging forces results in low weight/bucket size ratio. For a similar size of bucket its weight is roughly half that of a cable shovel. It's speed of travel is approximately double that of a cable shovel The horizontal crowd and wrist action permits loading of thin seams, compacted materials, and unblasted materials, and unblasted toes The machine is very effective in selective mining. Rate of material discharge from the bucket can be controlled to reduce impact load on truck pans. Excavates while standing in fixed position. Soft ground has little effect on its capability	A proven, reliable and low operating cost machine available with bucket capacities of $50m^3$ Owing to the rigid stick and bucket design no wrist action is possible—a disadvantage in unblasted toes Its digging path approximates a quadrant of an ellipse with a vertical major axis. The bucket digs the material throughout most of the digging cycle; mining of thin bands and selective mining is not of forte of this machine Its digging action requires that material be dug from a horizon of approximately the same as the machine is working at. Cannot dig below the working level It cannot traverse gradients greater than 1 in 20. With the shovels mechanism of discharging its bucket load, no control over the dump rate is possible Has a long life 20-30 years and low operating costs compared with either a hydraulic shovel or a front-end loader	A versatile machine, highly mobile capable of speeds of up to 45km hr, can be used as primary loaders, clean-up machine load and haul machine and as a dozer Are being increasingly used as load-haul-dump machines Lack of stability and traction problems result in higher loading cycle Staggered tandem and chain loading methods overcome some of the cycle time limitations Bucket is designed to be wider than the width over the front tires in order to protect tires. The width per unit capacity of this machine is higher than for other excavators Tire replacements costs contribute substantially to operating and maintenance costs Not suitable for soft ground cannot dig below grade, drives forward to excavate and load resulting in severe damage to undercarriage Operates while moving so danger of overturning or falling over edge Ideally suited as a loader for well fragmented ground on good under-footing. Also used in haul road maintenance, stockpile reclamation clean up in the pit and as a back-up machine

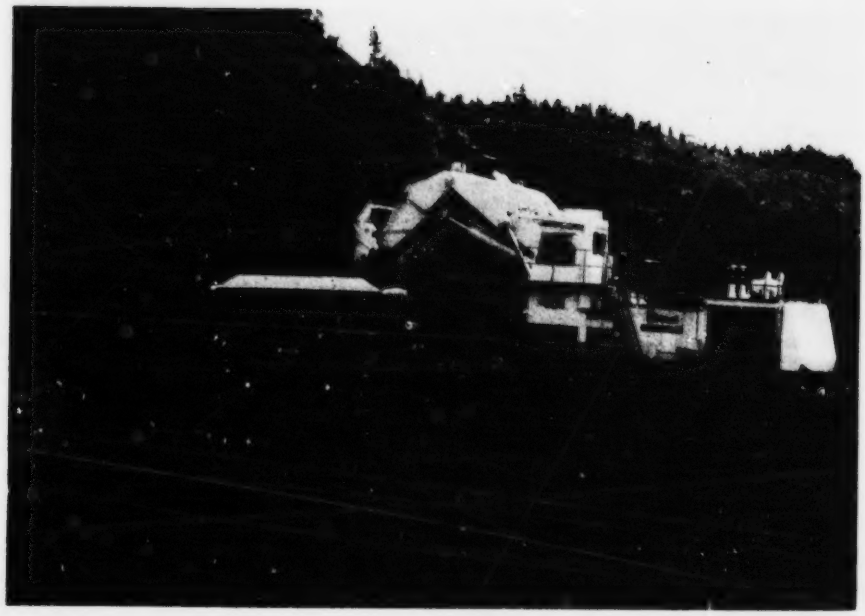


Fig 4. Demag hydraulic shovel at Westar Mine

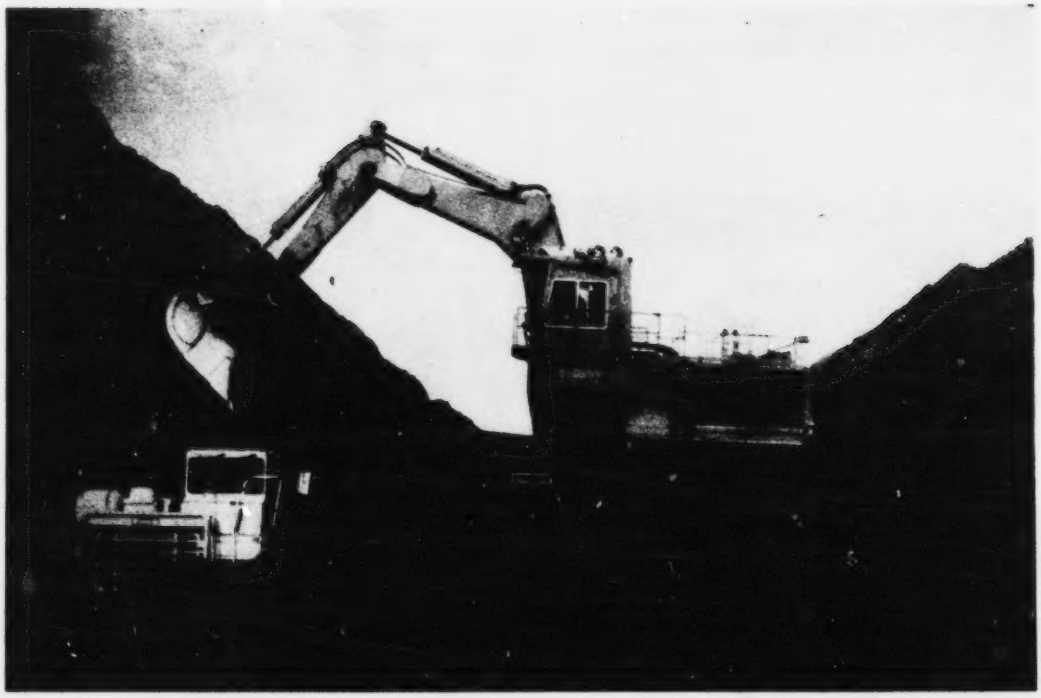


Fig 5. Hydraulic shovel used as a backhoe

Fig 6. Hydraulic shovel digging hard rock at a copper Mine

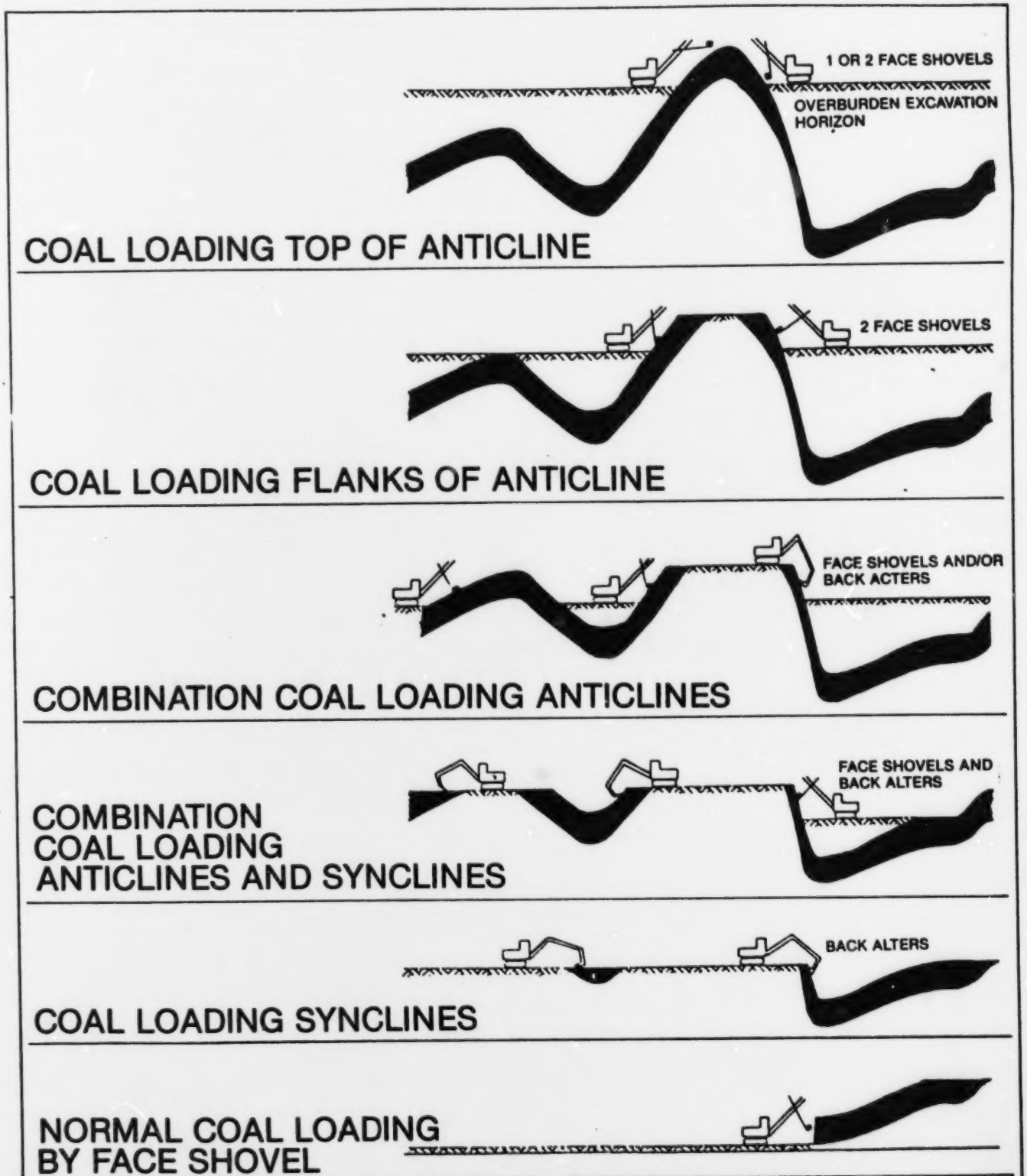

1 OR 2 FACE SHOVELS
OVERBURDEN EXCAVATION HORIZON
COAL LOADING TOP OF ANTICLINE
2 FACE SHOVELS
COAL LOADING FLANKS OF ANTICLINE
FACE SHOVELS AND/OR BACK ACTERS
COMBINATION COAL LOADING ANTICLINES
FACE SHOVELS AND BACK ALTERS
COMBINATION COAL LOADING ANTICLINES AND SYNCLINES
BACK ALTERS
COAL LOADING SYNCLINES
NORMAL COAL LOADING BY FACE SHOVEL

Fig 7. MINING FOLDED SEAMS WITH HYDRAULIC SHOVELS

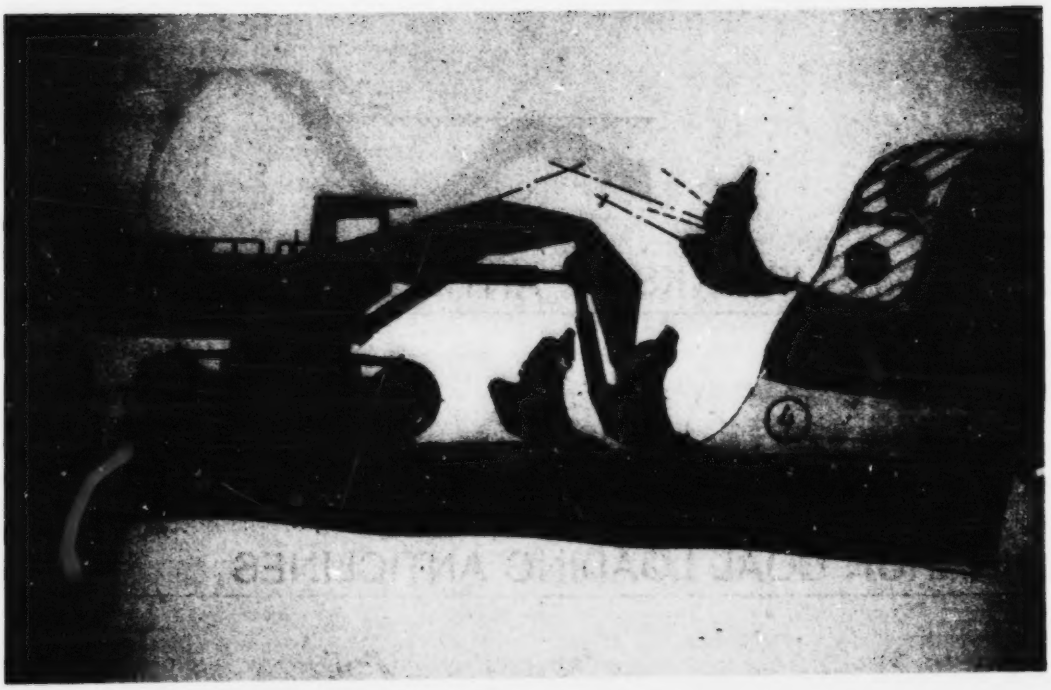


Fig 8. Selective mining with a hydraulic shovel

mining. Due to shorter angle of swing, the cycle time for a given duty is lower and the productivity correspondingly higher.

All classes of loading equipment have undergone design changes, including the incorporation of health monitoring systems resulting in increased reliability and improved performance. In turn, this has resulted in lower unit cost of production. Equipment size mix has also changed to make loading equipment more compatible with hauling equipment.

In the case of cable shovels particular mention must be made of the Acutrol system incorporated in Bucyrus-Erie's cable shovels. The Acutrol is a static AC control and drive system offered by Bucyrus-Erie Company and manufactured by either General Electric or Siemens. The AC system offers numerous advantages over more conventional static DC drives. It provides an excellent average power factor; tolerance of momentary voltage fluctuations of 10 to 30% without shutdown or component failure; full electrical braking during loss of incoming power and lower harmonics of any static excavator drive. In terms of shovel performance it provides high digging speeds; faster handle retracting, reduced swing cycle time, improved hoist acceleration and high continuous propel gradeability. Because AC motors have better thermal (overload) protection than DC motors and can operate near stall conditions for an extended period of time, the Acutrol power system also provides better digging capability in hard materials without motor damage.

Hydraulic shovels are produced by several manufacturers in various sizes. The main components of a hydraulic shovel are undercarriage, upper structure, digging attachment, prime movers either diesel engines or electric motors, hydraulic pumps etc. The hydraulic cylinders used for boom maneuver generate enormous forces to be taken by the structural steel work. Machines designated for use in sub-zero climate must have load bearing components made from cold - weather steel. Hydraulic shovels operating in northern Canada where temperatures dip to -45° C or lower embody special features viz

- load bearing components as well as bolts subject to high stresses must be made from cold weather steel
- heating of engine cooling water is provided when the machine is idling
- heating elements for warming the hydraulic oil
- pre-heating of batteries by means of hot plates

Hydraulic shovels with dual type of prime movers are available although this option increases the cost. A diesel engine operated shovel can be converted to an electric powered machine and vice versa.

Another development which is being increasingly applied to surface mining loading equipment and is available as an option is the health and performance monitoring technology. This is achieved by using an on board

SHIFT TIMES: 5:00 to 17:00 DATE SHIFT BEGAN 23/FEB/86

1. PRODUCTION SUMMARY: (DENSITY = 1.50 T/CM, BUCKET WT = 37.T)

A. PRODUCTIVE DIGGING

	TIME ANALYSIS		RETURN MAT.		DIGGING ANALYSIS		
CODE DESCRIPTION	HOURS	%T	TONNES	CM	TONNES	CM	CM/HR
00 STRIPPING	6.64	55.33	46.	30.	24789.	16533.	2490.
02 KEY CUT	1.04	8.66	0.	0.	3315.	2210.	2125.
08 TRAINING	0.75	6.25	0.	0.	2041.	1361	1815.
14 OTHER DIGGING	0.14	1.16	0.	0.	486.	324.	23.
SUB TOTAL	8.57	71.42	46.	30.	30631.	20368.	2377.
B. NON-PRODUCTIVE DIGGING							
15 REHANDLE	0.66	5.50	0.	0.	2460.	1636.	2478.
16 ROADS	0.33	2.75	0.	0.	1230.	818.	2479.
SUB TOTAL	0.99	8.25	0.	0.	3690.	2454.	2479
TOTAL	9.58	79.82	46.	30.	34322.	22822.	2382.

2. WALKING SUMMARY:

	HOURS	%T	NUMBER OF STEPS
18 NORMAL WALK	0.17	1.42	12
19 OTHER WALK	0.03	0.25	2
TOTAL	0.02	1.67	14

3. OPERATOR DELAY:

	HOURS	%T
22 SHIFT CHANGE	0.07	0.59
23 MEALS	0.52	4.34
26 BLASTING	0.20	1.66
TOTAL	0.79	6.59

4. OPERATING MAINT:

	HOURS	%T
40 DUMP RIGGING	0.15	1.25
42 TEETH	0.13	1.08
TOTAL	0.28	2.33

5. ELECTRICAL MAINT:

	HOURS	%T
55 HOIST GENERATOR	0.54	4.51
TOTAL	0.54	4.51

6. MECHANICAL MAINT:

	HOURS	%T
TOTAL	0.00	0.00

7. SYSTEM:

	HOURS	%T
100 UNIDENTIFIED	0.61	5.08
TOTAL	0.61	5.08

PRINTED 23 FEB/86 AT 17:25 TOTAL HOURS RECORDED THIS REPORT

Fig. (9) A typical report generated by computerized mine management system (Digmate System for Draglines - General Electric).

performance monitoring technology. This is achieved by using an on board computer and a variety of sensors. Such systems available from the shelf are now in use on shovels, front-end loaders, draglines, scrapers and dozers. They monitor engine, drive train, hydraulic and lubrication systems to provide immediate warnings of impending systems failures before they occur. Periodic system checks can also be made by the operator to alert him to potentially hazardous conditions. Performance data, operating time and machine utilization, which has been recorded during regular work hours is contained in tabular form and on histograms for maintenance and operating management (Fig 9).

DRAGLINES

Draglines, when correctly applied, give the lovest unit cost of overburden removal compared with all other equipment except a bucketwheel excavator. Draglines can handle coarse material, can dig above and below grade and are capable of selective mining. The major disadvantages of a dragline is its lover breakout force compared with shovels, small transport distance requiring rehandling of materials and high initial capital cost.

In the majority of the surface mine operations the removal of overburden represents a significant portion of the overall cost. As the overburden cover lying over a coal seam increases so does the cost of its removal. In such situations draglines have longer cycle times because of chop down for bench formation and because of deeper digging. Methods have been proposed and applied to remove some part of the upper overburden by a supplemental mining system, so that the dragline continues to dig at its peak rate without a need to rehandle material. The methods to remove the upper overburden include scrapers, shovel/trucks, a long boom dragline and bucketwheel/conveyors, Fig (10).

There is however general agreement that for overburden depth of upto 30m and providing the geometry of the deposit and other mine planning issues permit a dragline is the most economical machine. For overburden depths of between 30 to 45m either a dragline with a long boom or a tandem dragline should be considered. At depths of 45 to 60 m a single dragline is not competitive and a pre-stripping system should be considered to support it.

CONTINUOUS MINING SYSTEM: BUCKETWHEEL EXCAVATORS - CONVEYORS

The main components of a continuous mining system are shown in Fig (11). The system comprises the bucketwheel excavator to continuously dig the material; conveyors to transport the material; trippers to transport the material from the conveyor to the spreader and spreaders to dump and spread the overburden by low or high dumping. However, the life line of a continuous surface mining system is a bucketwheel - conveyor combination. Conventional bucketwheel excavators have been used in Europe for decades in high volume surface mining operations and are finding increasing acceptance in many other parts of the world.

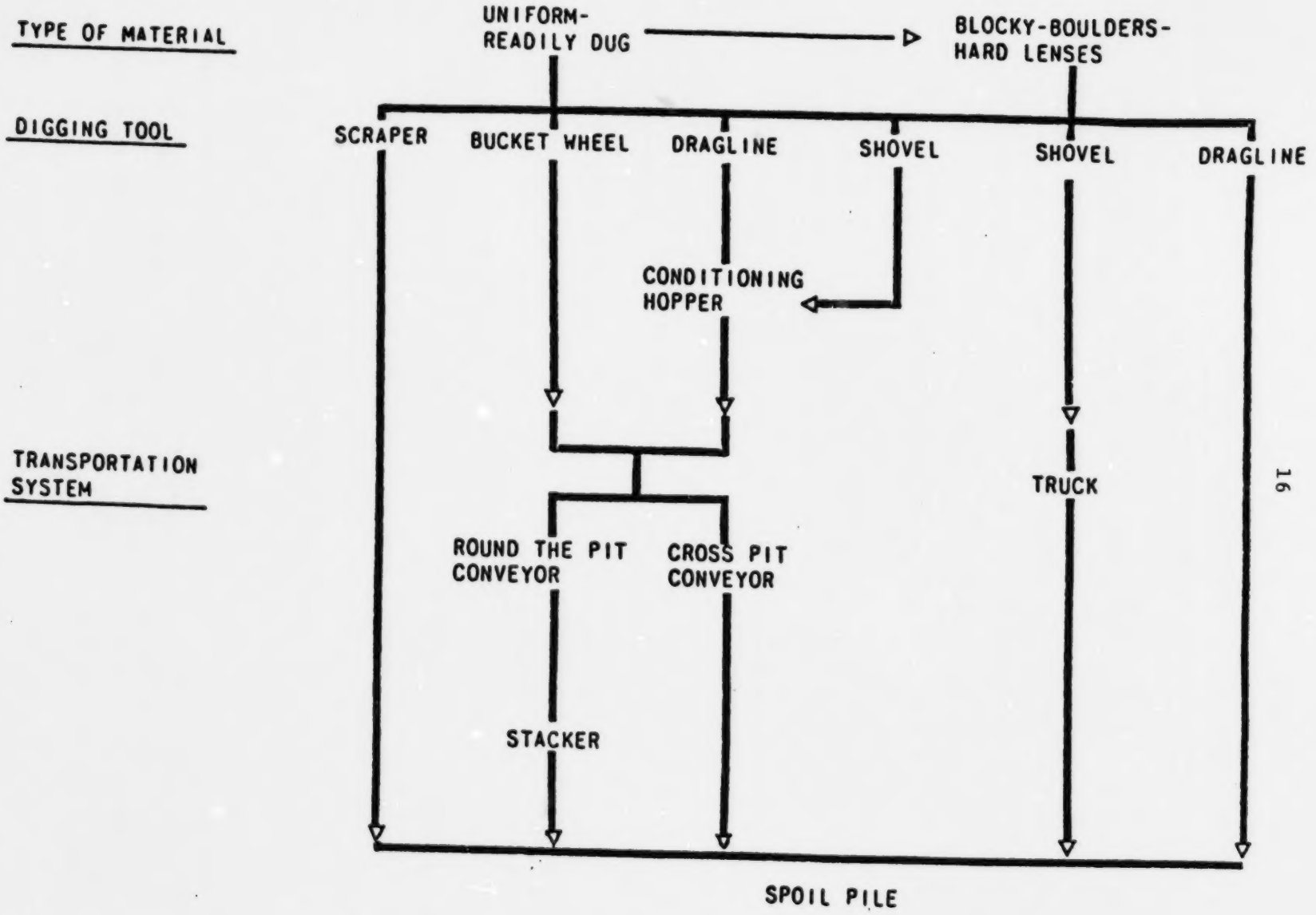
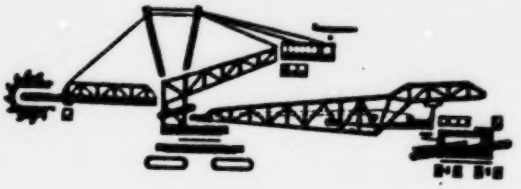


Fig 10. UPPER OVERBURDEN REMOVAL METHODS
USED IN CONJUNCTION WITH A DRAGLINE

COMPACT BUCKET WHEEL EXCAVATORS

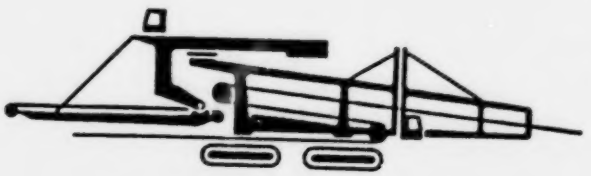
LARGE-SCALE EXCAVATORS



CONVEYOR BRIDGES AND BELT WAGONS

BELT CONVEYOR SYSTEMS

TRIPPER CARS



SPREADERS

MAIN COMPONENTS OF A HIGH-VOLUME CONTINUOUS SURFACE MINING SYSTEM

Fig 11.

A bucketwheel excavator, produces small sized material, can dig above and below grade onto a variety of haulage modes including trucks and belt conveyors and is capable of selective mining. Its main disadvantage is its lack of mobility and its unsuitability in digging consolidated materials. In some instances material to be handled by bucketwheels is blasted to facilitate digging.

The production rate of a bucketwheel excavator depends on many parameters of bucketwheel design, the nature of the materials to be excavated and the method of working a face. The number, shape and size of buckets, design of digging wheel and its diameter, length of the load boom, wheel rpm, slew and lifting speeds, and travel speed are some parameters associated with equipment design. The cuttability, plasticity, stickiness and moisture content influence the properties of the material to be excavated whereas design of cuts, geometry of the mining face in particular its height, width and slope angles relate to the method of excavation.

Conventional bucketwheel excavators are available in various sizes. The largest is capable of handling 240,000bm^3/day. For small to medium size operations a series of all hydraulic compact bucketwheel excavators and belt wagons are available. The output range of these machines is between 300 and 2000 bm^3/hr. (Fig 12).

These machines can be equipped with either electric or diesel power drives. The bucket wheel drive, boom lifting, slewing and traversing are all accomplished hydraulically. They have high mobility and are better able to cope with peak digging forces and changing excavating conditions. Delivery time of these excavators is short and the price relatively low.

TRANSPORTATION BY CONVEYORS

Belt conveyors provide an economical method of transporting large volumes of materials in surface mines. They are an integral part of the continuous mining systems. Although their initial cost is high operating costs are much lower. They are reliable and can achieve 90 - 95% availability.

There are many types of conveyors - shiftable conveyors, curved conveyors and mobile conveyors which are either on tracks or tires and which are moved about frequently. There are telescopic headstations and walking headstations which increase the scope of conveyor utilization and make conveyor moves easier and less time consuming. The intent of all these developments in conveyor technology is to transport material at the lowest unit cost.

High speed belt conveyors with the present technology can achieve speeds of up to 7.5m/sec; depending on its length and the material transported such a conveyor can be powered with upto 6 x 2000 kW units. For most long haul high lift applications steel cable belts are used. A 3.m wide belt is not

Fig 12. Demag compact all-hydraulic bucketwheel excavator-HD710

uncommon on high volume operations handling 30-40000 tonnes/hr. of materials.

A new competitor to long belt conveyor systems is the cable belt conveyor. The system is by no means new in origin but like other equipment described here it has undergone substantial design changes and consequent improvement in performance, reliability and operating cost.

A special feature of the cable belt system is the separation of the driving medium from the material carrying medium. In conventional systems the belt must be capable not only of carrying the material load but also transmit the driving tension. In the cable belt system the material is carried on a transversely stiffened but longitudinally flexible belt riding on two endless loops of cables that transmit the driving tension. (Fig. 13).

The drive cables with the belt sitting on them are supported on pulleys spaced at regular intervals along the conveyor. The belt is positively located on drive cables by the "V" shoe forms. Drive cables are located in grooves onthe supporting pulleys, range indiameter from 32mm (1 1/4") to 64mm (2 1/2") and can be sheathed in synthetic rubber.

Many of the economies in using cable belt conveyor systems emanate from the line equipment. Less line equipment and less moving parts are required to support the cables and belting. This results in reduced foundation and installation work compared to conventional type systems.

HIGH ANGLE AND CROSS PIT CONVEYORS

During the last five years, considerable research and development effort has been directed towards developing high angle, elevating and cross pit conveyors.(Fig. 14) Such conveyors where applicable can result in substantial reduction in transportation costs per unit of material handled. Even greater economy can be realised by changes to mine plans possible with such equipment. Elimination and re-positioning of some haul roads in a deep pit can reduce waste to be handled by millions of cubic metres.

The first prototype high angle conveyor (HAC) was developed by Continental Conveyor and Equipment Co. Inc. Alabama, U.S.A. This system uses a mechanically pressed "sandwich" belt. The 30.5 m long prototype unit had a 1.52 m wide belt and could be elevated up to 60°. Many types of materials including coal and lignite under wet and dry conditions were tested with throughputs of up to 2700 tonnes/hr. In 1984 one such conveyor was installed by Continental at Triton Coal Co., Buckskin Mine, Wyoming, United States. This conveyor has 33 m of lift operates at a 60° incline and can handle coal at 2000 tonnes/hr. (Fig. 15)

A second HAC will soon be erected at the Majdanpek copper mine in Yugoslavia. This conveyor will be an integral part of an in-pit crushing and conveying system and will elevate the crushed ore from the pit onto an out-of-pit conveyor system which will convey the ore to a processing plant.

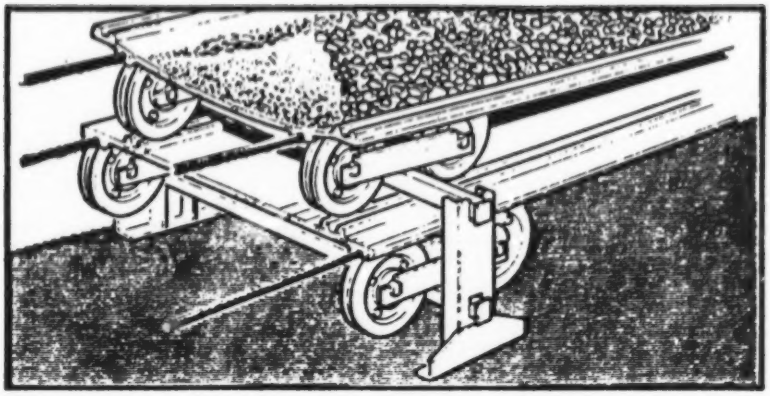


FIG. 13. SECTION OF CABLE BELT CONVEYOR

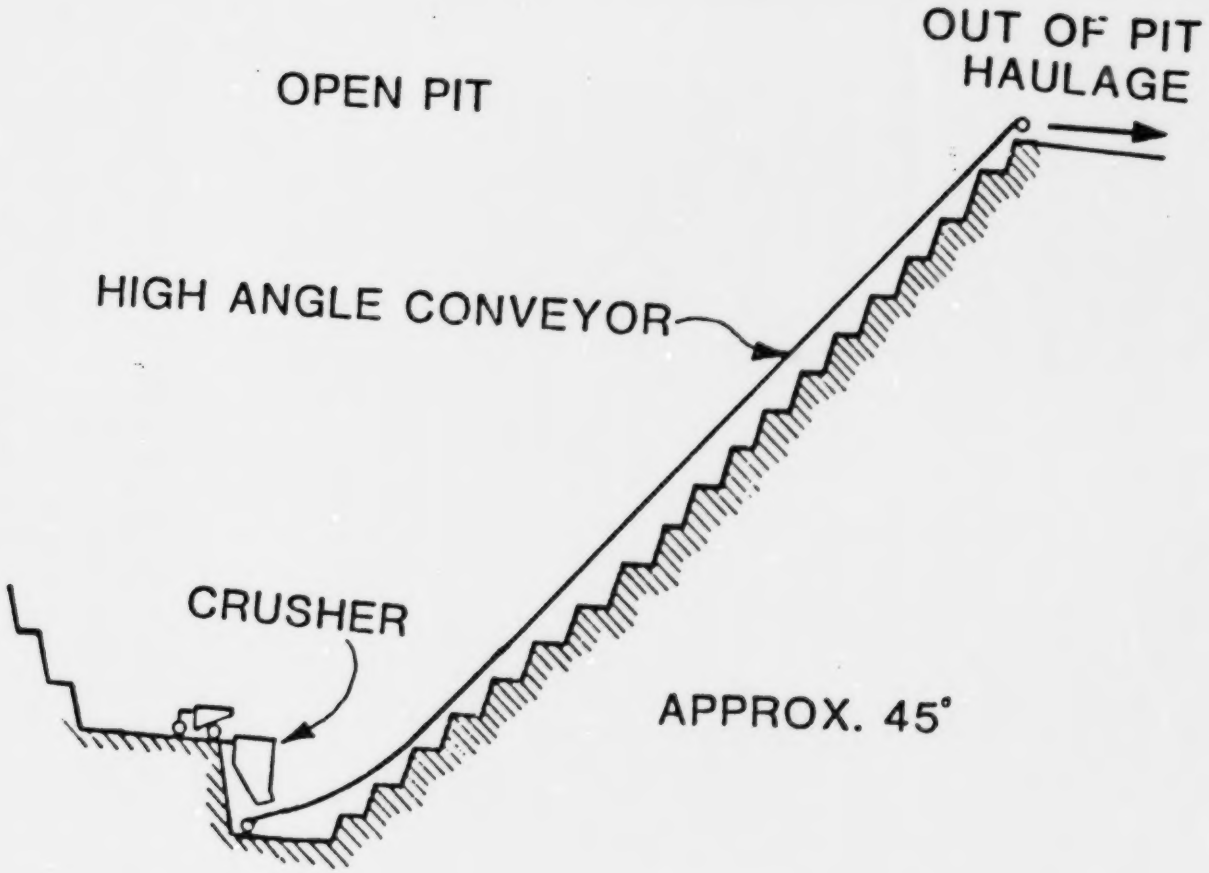


Fig 14 - high angle conveying system

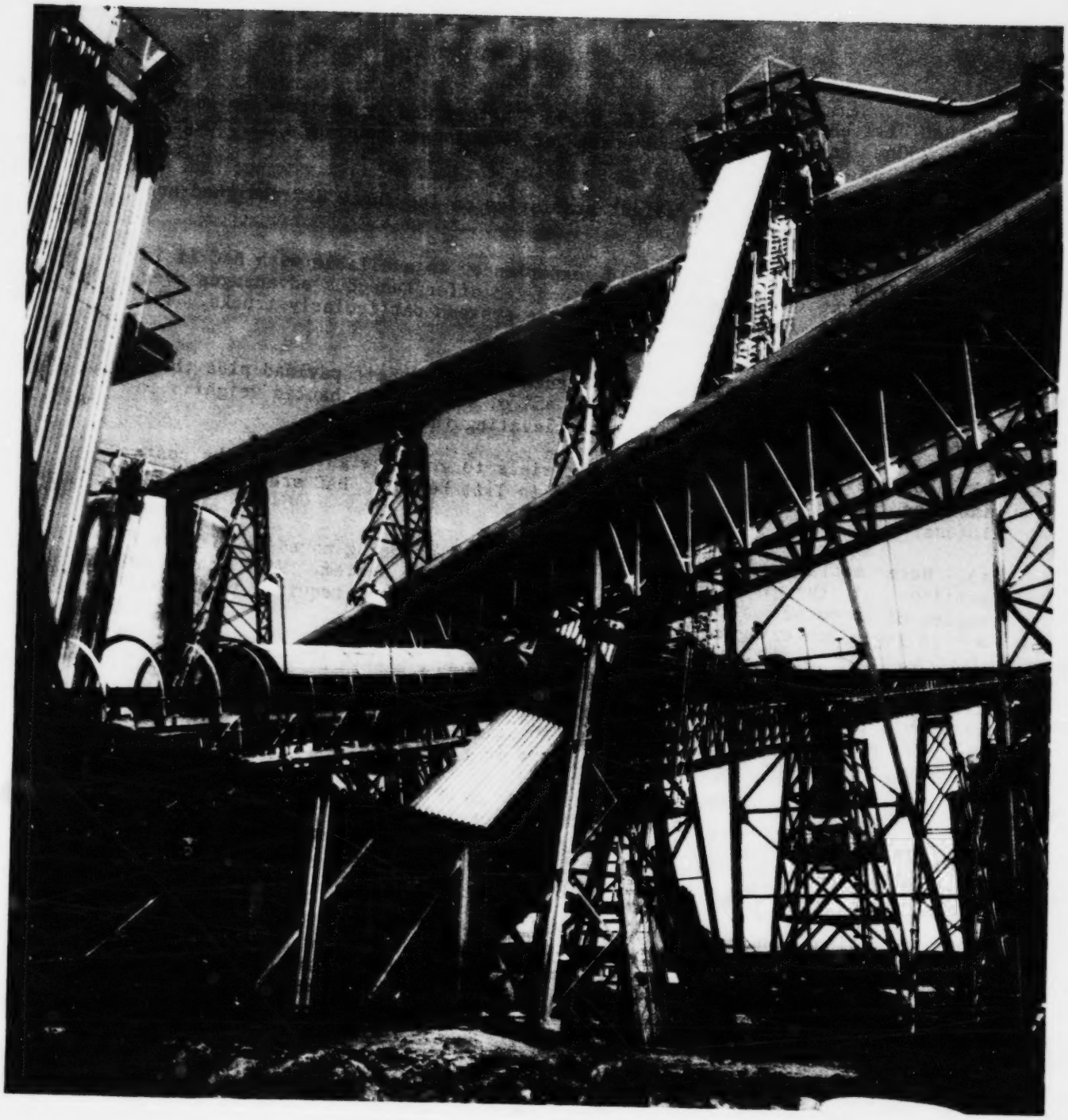


Fig 15. Continental high angle conveyor at Triton Coal Mine

This HAC will be 2m wide, have lift of 93.5 meters and is designed to convey minus 250mm copper ore at a rate of 4000 tonnes/hour up a 35.5 degree incline.

Table (4) gives the salient statistics on the three HAC designed and manufactured todate.

Although only limited field experience is available with HAC it is visualised that such conveying systems can offer numerous advantages over other modes of diesel consuming haulage systems particularly trucks. The HAC are:

a) More efficient energy users - trucks deliver their payload plus their own dead weight which can range up to 45% of total gross hauled weight. In a HAC much of the energy goes towards elevating the material.

b) More efficient for elevating materials to great heights - trucks costs increase exponentially with increase in lift height. HAC are less labour intensive.

c) More mobile - a HAC has the capability of being moved to different sections of the mine for more efficient use of the system. With conveying angles of up to 60^{o} the amount of additional excavation required to install a high angle conveying unit in minimal.

Additionally, HAC can be supported along any stable slope. Excavation required to install the conveyor is determined by geotechnical stability and not by 8 to 10% maximum slope required for truck haulage ramps. Some ramps can be eliminated entirely during the mine planning phase. In any event expense involved in maintaining the ramps in reduced.

High angle conveyors can be built with belt widths of up to 3m to carry up to 9000 tonnes/hr, provide a lift of over 300 m with steel cord belt and angles of slope up to 60^{o}. The conveyor can be mounted on rails, rubber tires, crawler type transporters and can even be fitted with walking mechanisim for optimum mobility. (Fig 16,17).

Variations in HAC designs are also available. For example, more recently Marion designed HAC for single lift and multiple lift pit operations. In this design a Flexovall pocket type belt is used instead of a mechanical sandwich belt. The conveyor can be equipped with either a fixed discharge for side-by-side loading of trucks, a hopper or a second highwall conveyor (Fig18).

A cross pit conveyor, as the name suggested is a conveyor transporting material across the pit. Combination of various conveyor schemes and configurations have resulted in around the pit conveyor etc. (Fig 19)

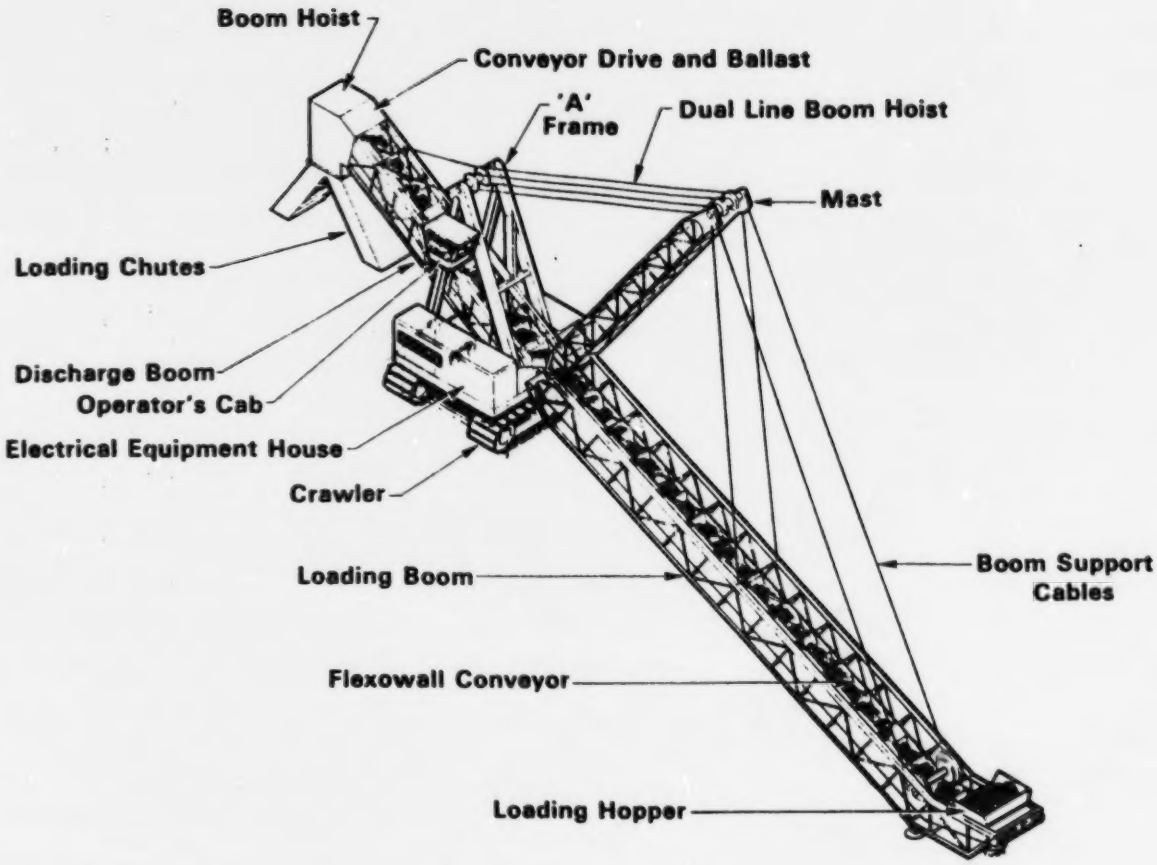


Fig. 16 - Marion-independently propelled crawler-mounted high angle conveyor

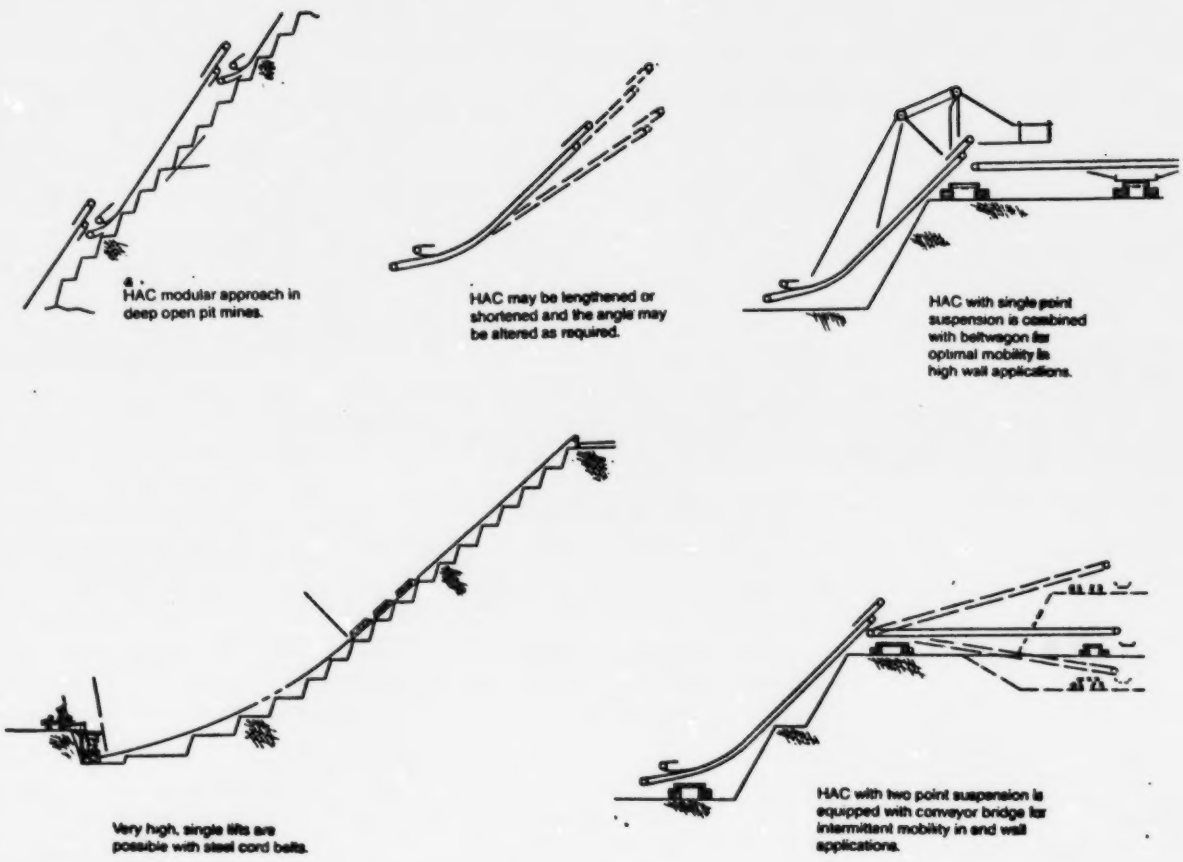

HAC modular approach in deep open pit mines.
HAC may be lengthened or shortened and the angle may be altered as required.
HAC with single point suspension is combined with beltwagon for optimal mobility in high wall applications.
Very high, single lifts are possible with steel cord belts.
HAC with two point suspension is equipped with conveyor bridge for intermittent mobility in and wall applications.

Fig. 17 - Possible variations in high angle conveyor design and application (Continental Conveyor Company)

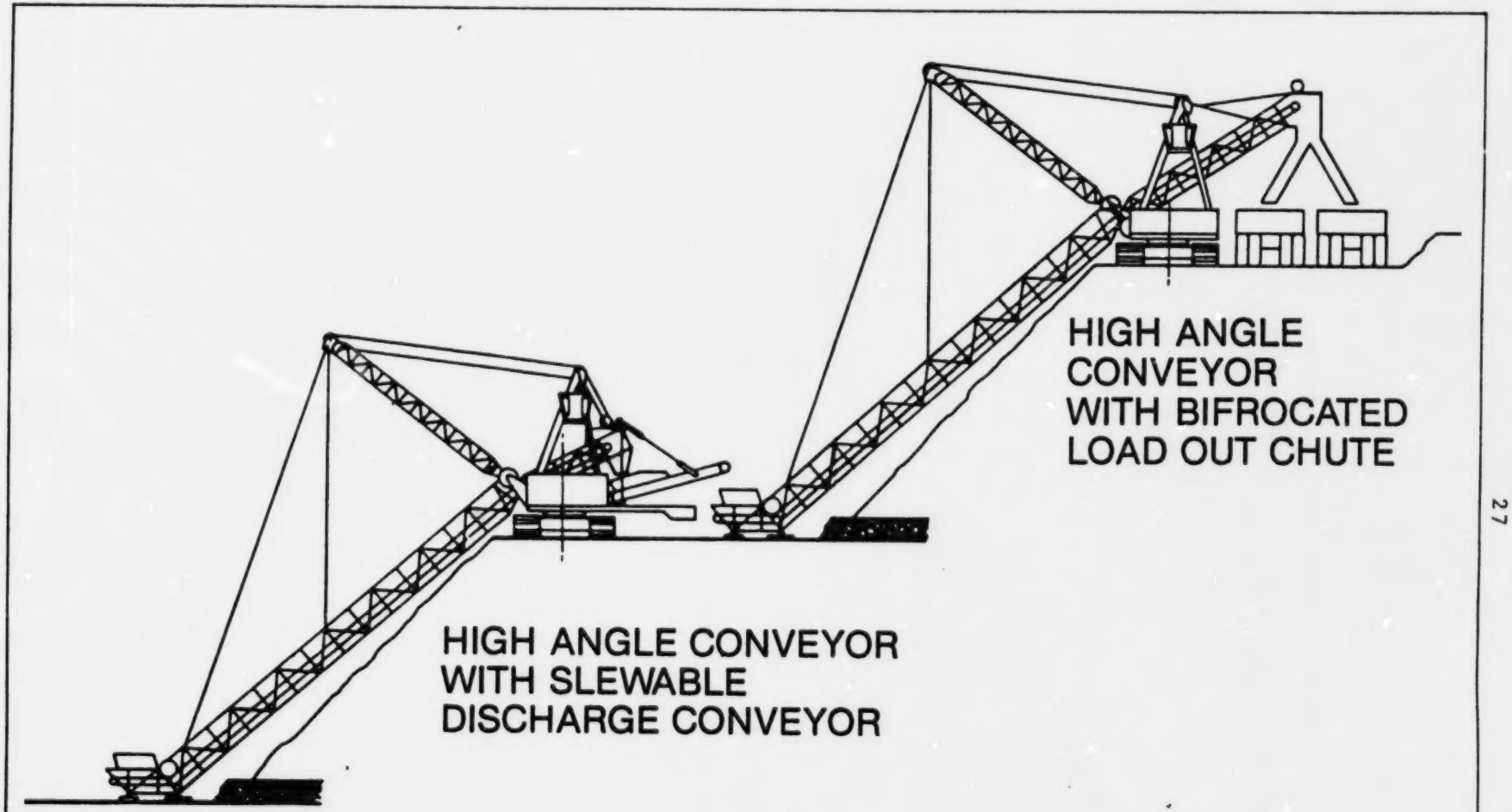


Fig 18.

TWO BENCH OPERATION OF HIGH ANGLE CONVEYOR

Table 4

HIGH ANGLE CONVEYOR - HAC® TEST AND DEMONSTRATION UNIT DATA

MATERIALS CONVEYED:	LIGNITE, COAL, COPPER ORE AND WASTE ROCK, IRON ORE PELLETS, SAND, GRAVEL, GRAIN
CONVEYING ANGLE:	VARIABLE FROM 30° TO 60°
DESIGN CONVEYING RATE AT 60° ANGLE:	1955, 2468, 2684 MTPH (2155, 2721, 2959 STPH) RESPECTIVELY FOR MATERIALS OF DENSITY .8, 1.6, 2.4 MT/CUM (50, 100, 150 PCF)
BELT WIDTH:	1524 MM (60 IN.)
BELT SPEED:	INFINITELY VARIABLE FROM 0 TO 6.1 M/S (0 TO 1200 FPM)
ELEVATING HEIGHT:	VARIABLE 7.9 TO 19.5 M (26 TO 64 FT.)
OVERALL CONVEYOR LENGTH:	35 M (115 FT.)
HAC CONVEYOR DRIVES:	
TOP BELT:	74.6 KW (100 HP)
BOTTOM BELT:	111.8 KW (150 HP)

TRITON COAL COMPANY HIGH ANGLE CONVEYOR - HAC® DATA

MATERIAL CONVEYED:	COAL
CONVEYING ANGLE:	60°
CONVEYING RATE:	
DESIGN:	1814 MTPH (2000 STPH)
SURGE:	1996 MTPH (2200 STPH)
BELT WIDTH:	1524 MM (60 IN.)
BELT SPEED:	4.65 M/S (915 FPM)
ELEVATING HEIGHT, LOADING POINT TO DISCHARGE:	32.9 M (108 FT.)
HORIZONTAL PROJECTION:	
LOADING POINT TO SANDWICH ENTRANCE AT 0° CONVEYING ANGLE:	11.0 M (36 FT.)
SANDWICH ENTRANCE TO DISCHARGE:	25.6 M (84 FT.)
OVERALL CONVEYOR LENGTH:	56.7 M (186 FT.)
HAC CONVEYOR DRIVES:	
TOP BELT:	112 KW (150 HP)
BOTTOM BELT:	149 KW (200 HP)

HIGH ANGLE CONVEYOR - HAC® FOR MAJDANPEK COPPER MINE IN YUGOSLAVIA

MATERIAL CONVEYED:	COPPER ORE
DENSITY:	2.08 MT/M^3 (130PCF)
LUMP SIZE:	250 MM (10 IN.) MAX
CONVEYING ANGLE:	35.5°
CONVEYING RATE:	4000 MTPH (4409 STPH)
BELT WIDTH:	2000 MM (78.7 IN.)
BELT SPEED:	2.67 M/SEC (525 FPM)
ELEVATING HEIGHT:	93.5 M (307 FT.)
HAC CONVEYOR DRIVES:	
TOP BELT:	450 KW (600 HP)
BOTTOM BELT:	2x450=900 KW (1200 HP)

CONCLUDING REMARKS

One of the most important developments in loading equipment for the surface mining industry in recent years has been the hydraulic shovel. Its use is expected to expand providing stiff competition to cable shovels and front-end loaders. Hydraulic shovels have been incorporated in some novel material handling concepts such as hydraulic-hopper-spreader combination (Fig 20).

The most visible change in the industry is the greater application of conveyor transportation technology. A high angle conveyor is a very promising development and should contribute significantly to surface mine economics. The application of HAC technology and further developments in this area will be carefully monitored.

Development and acceptance of compact bucketwheel excavators and mobile conveyors have provided an opportunity to introduce continuous mining to lov volume operations.

Micro-processor based production information gathering and equipment health monitoring systems have been introduced and are finding greater acceptance within the surface mining industry. Their increased use is on the horizon.

ACKNOWLEDGEMENT

In preparing this reviev paper the author has dravn from numerous published and unpublished sources. The co-operation of equipment manufacturers, their field representatives and the staff of various research agencies particularly the U.S Bureau of Mines and National Coal Board U.K. is gratefully acknowledged.

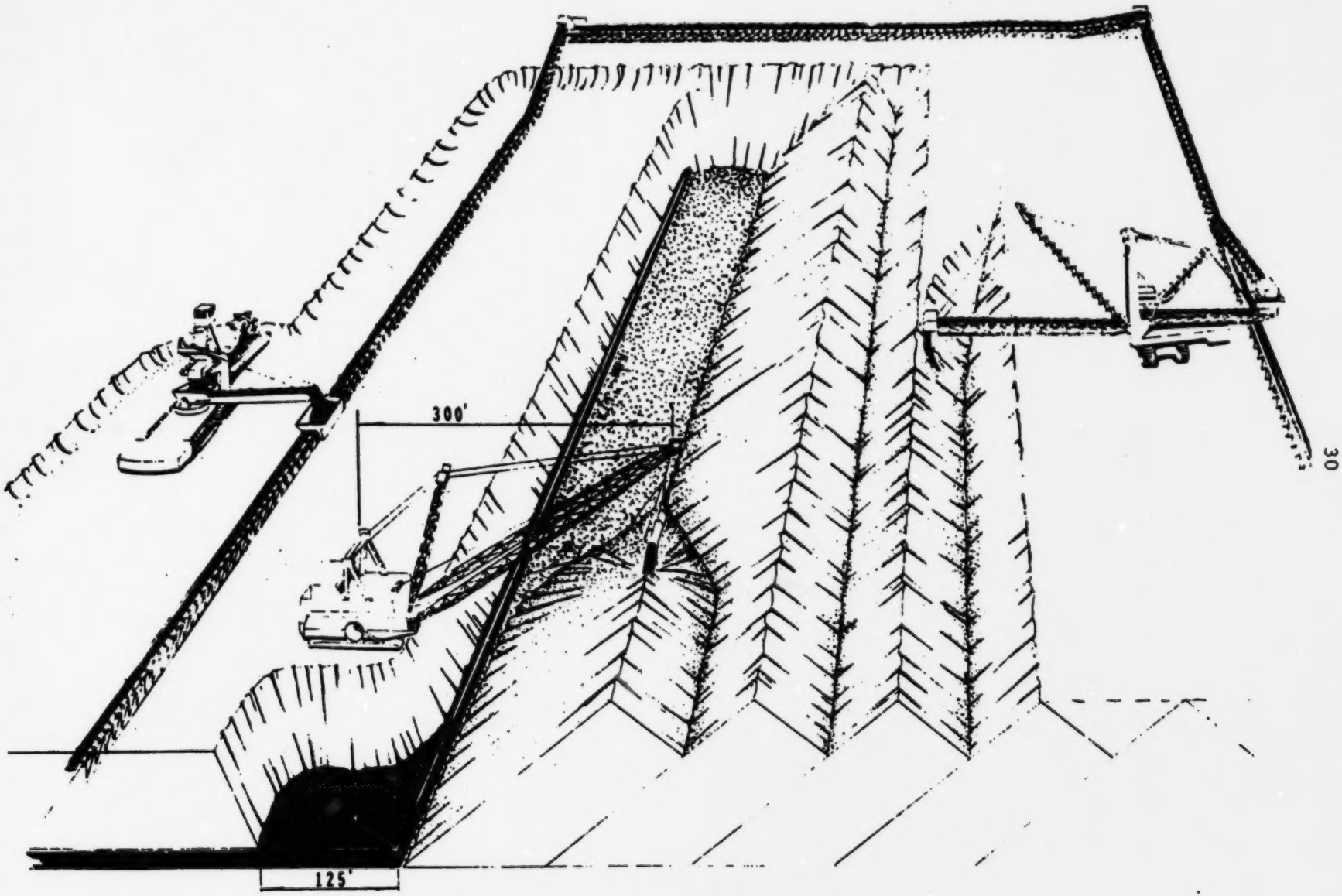
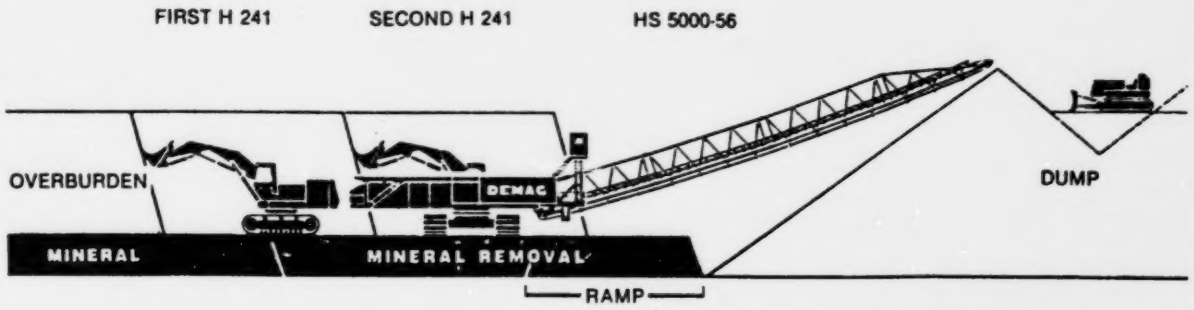


Fig 19. 2570-W 110 CUB. YD. BUCKET 300' REACH
ROUND THE PIT CONVEYOR BUCKET WHEEL LOADING WITH STACKER



HYDRAULIC SHOVEL EXCAVATES THE OVERBURDEN WHICH IS DUMPED INTO MINED OUT AREAS BY A HOPPER SPREADER

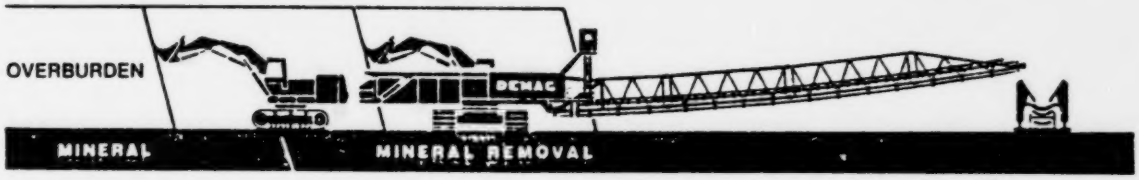


Fig 20.

HYDRAULIC SHOVEL LOADS THE BELT CONVEYOR VIA A HOPPER SPREADER